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1. Introduction

In the age of increasing tuition fees at UK Universities students demand more and better small group teaching. The purpose of small group teaching sessions can vary significantly and most certainly is different in course units with mainly discursive content. In the context of this paper we shall concentrate on small group teaching that takes place in a quantitative course unit where a significant purpose of the sessions is to expose students to quantitative problems. The most prominent examples here are Mathematics, Statistics and Econometrics course units.

A traditional approach to small group teaching in technical subjects has been to, initially, deliver core material during lectures. Subsequently students are asked to prepare exercises, in advance of the small group session, in which the tutor will lead the student participants through solutions. In terms of Blooms revised taxonomy, (Anderson and Krathwohl, 2001), the lecture allows students to develop low level understanding and knowledge of ideas, but then the act of preparing the exercises is designed to allow students to develop higher level learning, including the application of the material, analysis and synthesis. The small group teaching should then act to reinforce the higher-level skills.

While the above format can lead to excellent and useful small group sessions, when well prepared students use the opportunity to clarify any misunderstandings and issues encountered in the preparation with their class tutors, more often than not this does not happen. In the experience of these authors students that either do not turn up at all, come unprepared or are unwilling to significantly interact with their class tutors and/or peers often make tutorials designed according to the above blueprint ineffective in achieving the above aim[1]. In fact, the small group class may simply be reinforcing the low-level remembering and understanding, whilst providing little support for the development of higher level cognition.

The issue does not always and certainly not solely lie with the students. Often the class tutors are just too willing to deliver well-rehearsed problem solutions. Seeking interaction and input from students can often be difficult or uncomfortable and indeed tutors are unlikely to be trained in the necessary skills. Class tutors (often PhD students) may also be rather weary of student questions that lead into uncharted territory and away from their script.

Often the majority of students are just too happy to accept this situation as it allows them to disappear into anonymity and delivers full written solutions to problem sets they otherwise would struggle to solve unaided. Unfortunately, many tutorials in the more quantitative sub-disciplines of economics, including those of these two authors, do follow such a dispiriting pattern. The main issue that arises in this situation is that the class contact is used as delivery mechanism for worked solutions of problems. This could be achieved in different and cheaper ways. Perhaps more importantly, tutorials fail to deepen the students' understanding of the material nor do they develop students' generic skills through active participation.

[1] Tiberius (1999) lists a range of reasons why it may come to this stage, categorising them as either problematic or miscommunicated learning outcomes for the small group sessions, problems of group interaction or motivational issues.

Of course there have always been exceptions, extraordinary groups of students or teachers that wouldn't settle for lecture type tutorials. In recent years a technical innovation has emerged that greatly facilitates an approach that has the potential to deliver better outcomes. This innovation is the ability of lecturers and teachers to produce online video clips that can be used to deliver material.

Such clips have been popularised by Salman Khan through his khanacademy.org website. In fact Salman Khan has possibly been one of the most influential proponents of what has been called the flipped or inverted classroom. Inverted classrooms have become popular in secondary school environments (and in particular for mathematics) where online clips are used to deliver new material to students (traditionally done in the classroom) while the classroom sessions are used to support students actually working on problems.

The flipped classroom session has also found a foothold in the higher education (HE) sector. In HE most students receive different types of classroom contact. Lecture (large group teaching) settings are supplemented by tutorials or exercise classes (small group teaching). Any potential applications of the flipped classroom paradigm will have to differentiate between the purpose of these different settings. Traditionally large-group teaching is used to deliver new material and small-group teaching is used to work through problem sets which are typically meant to deepen the student's understanding of the material.

In this paper, we analyse, and describe, a flipped classroom approach, adopted in small group statistics and econometrics teaching at two, Russell Group[2], Universities in the United Kingdom, henceforth referred to as University A and University B. We analyse student responses to the efficacy of the new form of small-group teaching, and discuss how this flipped classroom may be used to improve the learning outcomes for students within small group classes.

The remainder of this paper is structured as follows. We proceed by describing the flipped classroom approach as applied in the context of this paper followed by a short literature review. In Section 4 we describe the experimental setup. The evaluation is presented in Section 5 followed by concluding remarks.

2. Description of Flipped Approach Adopted

The basic idea of organising tutorials as flipped tutorials is to allow students to spend the time in class together with a tutor in a way in which the presence of the teaching staff can make a significant difference to the learning process. In order to achieve this students get the opportunity to practice problems and see their solutions before they come to the actual tutorial meeting. Hence students receive a set of problems and an online clip with solutions about a week prior to the tutorial meeting. The online clip with worked solutions is produced by the course unit's lecturer and delivers about the same information to students that a traditional tutorial would have delivered, worked solutions to the set problems. In fact one may argue that this mode of delivering this information is superior to delivering these solutions through tutors in tutorials. It is delivered by the lecturer herself and all students receive a uniform delivery of this material. The disadvantage being that the students do not have the opportunity to interrupt the delivery and query the tutor.

[2] The Russell group is a group of 24 research intensive Universities, based in the United Kingdom

Importantly the actual tutorial meeting is designed to make more than up for that potential lack of interaction. The tutorial meetings start with the opportunity for students to query any remaining issues from the published problem sets. In our experience these discussions rarely take longer than 5 minutes. Next, students receive a new and unseen set of problems. Incidentally these problems will not be published in any other way. Students are then asked to work in small groups (3-5 students) and solve these problems. The groups are encouraged to use any available material (like lecture notes, textbooks, online clips) to support their efforts. They are told that the next hour is part of their learning process and not a test.

It should be said that in our experience the size of a tutorial group should not exceed 20 students (4 groups of 5 students). Larger groups should be serviced by more than one member of the teaching staff.

2.1 Design of the Problem Sets

It is useful to formulate the problem sets that are handed out in class such that certainly the first question on that problem set is in some sense a clear replication or slight extension to one of the problems that was published.

When designing the problem set the lecturer should not be too ambitious with the amount of material that ought to be covered. Progress in these tutorials tends to be slower than in traditional tutorials. It is, however, important to understand that in some sense the problems set in the tutorial are material delivered in addition to the problems and their solutions that are set online. They are meant to make the students practice their skills and there ought to be no pressure to cover material through these.

2.2 The role of the tutor

The role of the tutor, usually either very junior lecturers or PhD students, is then importantly to support the groups of students in the process of solving the questions. The tutor will circulate between groups and listen in to the discussions. If a tutor realises that a group is not progressing she may attempt to kick start the solution process. This can happen through guided questions like

- What lecture content does this problem refer to?
- Show me the chapter in the textbook that may help you here?
- Was there a question in the published problem set that relates to this problem?

The tutor will encourage students to present their solutions in an exam-style, such that they are encouraged to present their thinking and arguments in a written form. This gives the tutor the opportunity to scan the students' solutions as she circulates between the groups. She can then give feedback, not only on the core content of the answers, but also on its presentation.

It is also the role of the tutor to ensure that groups that complete a problem receive feedback on their solution. If they get essentially the right solution this is to be clearly communicated to the group. If their solutions are deficient then the tutor needs to point out where they are deficient such that the groups can revisit their approach[3]. In order to facilitate this process tutors are encouraged to note

[3] To facilitate this tutors are encouraged to mark-up a student's written solution as they see correct solutions (simple ticks) or problems.

down final solutions to questions on the whiteboard (or project slides with such final solutions). Under no circumstances are they supposed to publish worked solutions to these questions.

While the base mode delivery of these tutorials is that student groups work and tutors at any point in time devote their attention to one group only, there may come a point where a tutor realises that most or all groups are struggling with the same issue. In such a situation it becomes inefficient to communicate with individual groups and the tutor is encouraged to call the attention of all groups and address the common problem on the board in front of the whole class. Such an interlude, however, should attempt to only address a fairly small point and should not last longer than, say, 5 minutes. If the tutor anticipates[4], for instance, that students struggle with how to get started, then a tutor may also call the class together to briefly think about a solution strategy for a problem before letting the groups work on the actual solution.

2.3 The role of the students

Through virtual learning environments and clear communication in lectures students are told that it is the clear expectation that they come to tutorials prepared, even if that means that all they do before the tutorial is to watch the online solutions. It is of course recommended that students attempt the questions themselves before consulting the available online solution.

During the tutorial class tutors will encourage students to discuss with their peers. In particular students that don't understand proposed solutions ought to ask their colleagues to explain and students that seem to understand ought to explain to their colleagues; in that way testing their understanding. In our experience it will often require the tutor to encourage such discussions, in particular at the beginning of the semester in order to embed an understanding of how the flipped tutorial classes ought to work. By encouraging this cooperative aspect of student learning we hope to increase the amount of time in which students express their own views, listen to those of others and then discuss and debate in order to come to common conclusions. As discussed in Springer *et al.* (1999) evidence suggests that this will enhance student success.

2.4 Tutor skills and training

The skills that are required of a tutor in this setup are rather different than the skills we require of a tutor that delivers a more traditional tutorial. In particular a student ought to understand herself less as a teacher and more as a facilitator of learning. To be a successful facilitator it is important to be able to listen, question and respond to questions successfully (Edmunds and Brown, 2010). It is also important for tutors to observe the dynamics of the groups such as to evaluate whether all students are benefitting from the work.

Perhaps most importantly a tutor needs to be willing to engage with students and talk with them in a relaxed and supportive manner. An atmosphere should be created in which students feel that they can make mistakes. Hence tutors need to find ways to honestly comment on students' contributions without discouraging students from contributing.

While the Economics Network in the UK attempts to deliver a somewhat standardised training for postgraduate teaching assistants (Economics Network, 2016) that puts increasing emphasis on these

[4] Often tutors will lead several groups in a week and hence may have gained insights about points at which students struggle from previous meetings during the week.

skills recognising the increasing demand for useful small-group teaching, the amount of training tutors receive to improve the above skills is realistically fairly small. Moreover, tutors will often have no experience of their own of such flipped tutorials.

For these reasons it is recommended that tutors that are to be used in flipped tutorials receive additional instructions. We found it useful to schedule an additional (1 hour) meeting with tutors to talk through the specific approach adopted in these course units. Tutors were asked to prepare by reading through the following two papers. Steinert (2004) contains a useful discussion on what makes small group meetings successful. The paper by Edmunds and Brown (2010) discusses question and guiding techniques that can be useful to tutors whose main aim is not to teach but to facilitate. It also discusses a number of problems that can arise mainly in the context of mismatched expectation between teaching staff and students.

In addition it may be useful to use the first tutorial meeting for the lecturer to model a tutorial in order to allow new tutors to gain a good practical understanding on how flipped tutorial sessions ought to be delivered.

Finally, we recommend that course lecturers observe a tutorial early in the semester in order to provide constructive feedback to tutors that can be implemented for the remainder of the semester. As these tutorials do not involve a lot, if any, front of class teaching, observing such sessions is of the "fly on the wall" type and hence not without challenges as students are just too willing to direct questions directly to the lecturer.

2.5 Issues that arise

In our experience four issues arise from tutorials delivered in this way.

First, some students will arrive not prepared, i.e. they did not watch the online solution clip to make themselves familiar with the type of problems set[5]. When these students sit together with other students that have prepared it may feel to these groups that such students are a drag on their progress. To some extend the tutors are meant to encourage the students that are progressing on the problem to help the unprepared students along. Tutors are encouraged to remind students that being given the opportunity to explain something to another student is a great opportunity to test their understanding of the material. However, at the same time it is not desirable to halt the progress of the group for too long.

In situations in which a student can neither follow nor contribute to the progress of a group the tutor is encouraged to talk to the student and explain what he is expected to do in order to benefit from attending the tutorial. Identifying such students and having these discussions can be a fine balancing act and difficult for inexperienced tutors. It is, therefore, important that the course lecturer clearly communicates student expectations such that the class tutor can refer to these expectations.

Second, students will ask for completely worked solutions to the problem sets that are distributed in the tutorials. Both lecturers and tutors stress that these problems are additional problems that supplement the problem sets that are published prior to the tutorials alongside with their solutions.

[5] In the Evaluation Section we attempt to quantify the size of this group of students.

In our experience this will, not necessarily satisfy the student demands, but certainly keep them at a level that can be endured and ignored.

Third, some small groups during tutorials will have dominant students that breeze through the problem sets. An indication of this is when it will always be the same student that addresses questions and queries to the tutor. Tutors ought to be aware of this issue and check that the group as a whole is progressing through the material by asking other group members questions and facilitate intra-group discussions.

Fourth, some students may feel deterred from attending tutorials as they feel "put on the spot" by this particular setup which gives less opportunity to remain anonymous[6]. It is for this reason that it is important that the class tutor creates a relaxed atmosphere which allows students to make mistakes. But it should also be kept in mind that the setup described delivers all that was previously available (exercises and their solutions) before students come (or not) to tutorial classes. Arguably students are not worse off by adopting this flipped classroom approach.

3. Literature Review

In a traditional lecture, or teaching environment, where a lecturer or teacher delivers material, that the students attempt to assimilate and apply as part of individual assignments outside of a classroom, Mazur (2009) asserts that this "reduces education to a transfer of information". The key issue here is that the traditional educational delivery model of a single academic delivering content made sense in the early days of higher education, as books were relatively expensive, and a single academic could, efficiently, deliver content, which would otherwise be expensive for students to obtain (Mazur ,2009). However, with the relative inexpensiveness of books, and video technology, a growing number of educators are requiring students to acquire the knowledge outside of class, and using the lectures for other activities, with support from a lecturer. The act of initially acquiring the knowledge is, in terms of Bloom's revised taxonomy (Anderson and Krathwohl, 2001), allowing students to develop the initial, low level cognition relating to remembering and understanding, whilst in the lectures, students, with support from the instructor, are aiming to develop the higher levels of cognition, including application, analysis, and evaluation.

Whilst there is a growing literature on the impact of flipped learning, most of the literature is focussed on flipping within a lecture environment[7]. An example for this literature is the edited volume by Waldrop and Bowdon (2016) which collects a number of experience reports for flipped lectures from a range of disciplines. Due to ethical and logistical concerns, much of the literature is unable to gain a causal estimate of the impact of a flipped classroom on grades or student satisfaction, as there is often non-randomness in the assignment of the treatment, or there are not clear control groups employed.

3.1 Evidence of impact

The impact of flipped lectures has been considered widely in other academic areas, such as in science, with results regularly showing large, significant positive impacts of flipping. However the literature

[6] One may suspect that this may particularly apply to some specific student groups, e.g. overseas students with increased language barriers. The data available to us are not rich enough to investigate this aspect.

[7] The authors have been unable to find examples of flipped classrooms for tutorials in higher education, although the practice of student-centred learning is commonplace in high schools.

often does not gain a credibly causal impact. Many papers will assess students' perception of the flipped classroom environment and perhaps compare grade distributions across different years. The general findings are that students prefer the flipped classroom approach (e.g. Waldrop (2016) who uses student questionnaires and focus groups) and that student grades improve when compared to previous, more traditional deliveries (e.g. Thompson and Martin (2016) where grades improve marginally and Garver (2016) who reports more dramatic improvements).

There are some attempts made in the literature to provide controlled experiments to assess the impact of a flipped lecture on assessment grades. For example, Deslauriers et al (2011) considered a controlled experiment where two Physics classes were taught the same material, but one class was flipped, whilst the other was taught using traditional methods. The results suggested that students in the flipped classroom performed 33 percentage points better than those in the traditional classroom. Even with control and treatment groups, since assignment of students is, likely, non-random, the lack of controls for heterogeneity, and different teachers mean that the results cannot be interpreted in a causal way. In a similar experiment Yestrebsky (2016) established that attending large flipped chemistry classes may help good students to attain even higher marks, but may have little or no positive impact for weaker students. Berrett (2012) argues that traditional methods of teaching placed the role of teaching concepts in a calculus class on the teacher, whilst for the most difficult part, solving problems, students were left on their own. Berrett (2012) cites a case study from Ann Arbor (Michigan), in which a maths class were flipped. Again, non-random assignment of students to treatment means that the results are unlikely causal, but he observes gains in learning.

Within economics, there are a number of recent studies, examining the impact of a flipped classroom, with credible identification strategies. Olitsky and Cosgrove (2016) combine a flipped lecture with a blended learning environment, and use a difference-in-difference strategy to estimate the impact of a flipped classroom. Their results suggest a modest improvement in students in the flipped environment of about 7% compared with their non-flipped peers. Calimeris and Sauer (2015) examine the impact of a flipped classroom on exam grades and student perceptions in an introductory microeconomics class; they utilised a randomised experiment, with controls for heterogeneity, and found improvements of 0.5 standard deviations in exam results for students in the flipped classroom. In terms of students perceptions, Calimeris and Sauer (2015) report that the majority of students valued access to lecture videos, and a small majority agreed that they preferred the flipped format over a traditional format of teaching. Roach (2014) adopted a partially-flipped lecture class over the course of one semester in introduction to microeconomics. A majority of students report that flipped learning helped them to learn, and a large majority reported that the classroom was more interactive than other classes; however, Roach (2014) makes no attempt to provide a controlled comparison for students to report changes in perception. Similarly, Lage et al (2000) attempt to utilise a flipped classroom environment to gain inclusivity in education; their results suggested that students preferred the inverted classroom to a traditional lecture, and suggest that female students may particularly benefit from a flipped environment. The majority of the literature uses video instruction over the internet to deliver the course material, and then engage in student-centred engagement in class (e.g. Calimeris and Sauer (2015), Roach (2014), Olitsky and Cosgrove 2016). One concern is that the reported effects are merely benefits gained by making videos available of lectures, and no benefits are gained from the engagement in class. This worry is, partially, assuaged in the literature, with studies suggesting that students taught entirely in virtual classrooms perform significantly worse than those taught in a live lecture environment (Figlio et al (2013), Brown and Liedholm (2002)). These

results suggest that the mechanism at play is not simply a benefit from watching a video of a lecture, rather than sitting in a live lecture. However, one possibility is that the significant positive results seen in much of the literature of a "flipped" environment could just be that on top of the material that is in the online video, students are receiving additional tuition within the class.

4. Experimental Setup

The approach explained above was introduced in three course units at two large UK based Russell Group universities in similar style course units. At University B, the flipped classroom was introduced for the second semester of a Year 1 course unit, Quantitative Methods (300 students). At University A, it was introduced in Semester 2 of the second year Econometrics course unit (300 students) and a second semester Year 1 Introductory Statistics course unit (250 students). The respective first semesters tutorials were held according to the more traditional front of class approach. While the Introductory Statistics unit (University A) had no first semester part, it did have a pre-requisite course unit (Introductory Mathematics) that all Statistics students had to take and in which tutorials were held in the traditional manner. This allows us to ask questions that let students comment on the relative strength of the different approaches.

The tutors used in Semesters 1 and 2 were largely the same, although it was well possible that individual students from University A changed their tutor from Semester 1 to 2. For University B's Quantitative Methods unit students remained with their tutors throughout Semesters 1 and 2. One of the inherent weaknesses in the literature of many studies is the inability to gain a controlled experiment. In contrast to Lage et al (2000), we are able to make much more causal inferences about the impact of flipped tutorials on student perception (particularly for University B), as students were experiencing tutorials in the *same subject*, led by the *same tutor*, and with the *same peer group*, allowing us to observe a natural experiment. The only, within class, heterogeneity that remains is the actual material that is covered.

As the material progresses significantly from semester 1 to semester 2 we refrain from comparing the respective exam results. Such an analysis would further be complicated by the fact that different lecturing staff were employed for the different semesters. We asked questions that attempt to illuminate how students used the material that was provided but also asked for free text responses and held interviews with a small number of students and tutors. Our approach can therefore be best described as a mixed methods approach.

Given the nature of the evidence collected we will refrain from making overly strong and generalised conclusions on the effectiveness of the flipped approach. However we hope that the evidence provided here will serve to supplement and inform the personal judgement of any lecturer considering the introduction of flipped tutorials will have to make.

5. Evaluation

5.1 Data Collection

In order to evaluate the effectiveness of the flipped classroom approach we designed a questionnaire we asked students on the respective course units to complete. The two Universities utilised different collection methods; in the case of University A, completion of the questionnaire was online, and

students were granted access to extra revision material on completion, whilst the University B questionnaire was administered in a paper format, during a revision lecture. Further we collected some limited view statistics of the online clips which were used to provide solutions to the published problem sets. These statistics will be used to supplement and verify the evidence gathered through the student questionnaires.

In this paper we refrain from comparing grade statistics to those obtained from previous cohorts that did encounter small group teaching of the traditional variety. In all three course units exam papers can vary significantly from year to year and in the absence of a grade standardisation policy at either of the two institutions it is therefore common to see significant variations of grade distributions in consecutive years. It would therefore be impossible to assign any changes in grade distribution to the introduction of flipped small group classes.

5.2 Summary Statistics

5.2.1 Student behaviour

The first set of summary statistics (Table 1) reports on the number of students that responded to the evaluation questionnaires as well as the response frequencies to the question of whether students did watch the provided online clips with solutions to the published question sets before the actual tutorial.

The class sizes vary between 200 and 400 students and we receive responses to the evaluation questionnaire from between a half and three quarters of enrolled students. The tutorial class sizes vary significantly. The Quantitative Methods course unit has a class size of 15 students whereas the course units in University A, for these particular course units, operated on class two and three times the University B class size.

Tables 2, 3, and 4 show cross-tabs, showing whether there is a correlation between watching the online clips (question 1), and attending the tutorial classes (question 4). Using a Likert scale, with 1 representing "No", and 4 representing "Yes all", for Intro Stats (University A), we find a correlation of 0.36, for Quant Methods (University B), a correlation of 0.32, whilst for Econometrics (University A), a correlation of 0.35[8].

Student behaviour is clearly consistent across units and Universities in the sense that the students attending the tutorials are also the students that watch the online clips. However, Students in University B (Quantitative Methods) are somewhat more diligent, on average, both in terms of watching the online clips and attending tutorials.

Next we reflect on whether students substitute working on the problem sets with watching the online clips. Question 3 asks students to indicate how much time they typically spend tackling the problem questions themselves.[9] The cross tabs of responses to question 1 and question 3 are shown in Table 5

[8] The p-value on all of these correlations is equal to 0.0000

[9] Note, we now pool all students across the three units.

We can see a clear positive correlation (0.30, based on a Likert scale) between the two answers indicating that own work and watching online clips are complements rather than substitutes, although it is of course possible that individual students do substitute the two. There are, for instance, 8.4% of students who watch most or all of the online clips but do not attempt to answer the questions themselves.

The results to these questions are fairly consistent across all three course units and therefore we only show the combined frequencies.

5.2.2 Students' design preferences

We asked students to indicate which sort of activity they would prefer to see in their tutorials. The options they had to choose from were "Students working on unseen questions and tutors supervising" (this being the main activity in the flipped tutorials), "Students presenting solutions on the whiteboard to the whole class" and "Tutor working through questions on the board" (being the main activity of a traditional tutorial). Students had to indicate what percentage of the tutorial time they would prefer to have allocated to these three activities.

Summary statistics of the students design preferences are shown in Table 6. These summary statistics clearly indicate that students, if left with the task of designing tutorial sessions, would predominantly ask tutors to solve problems on the board, although many students would also reserve significant proportions of time to let students work through problems. While students presenting solutions to the entire group is not very high up on the student's priority list, more than half of students would actually prefer to have some time devoted to this activity. University B students tend to have a preference for tutorial sessions that concentrate on one of the two main activities, whereas students on the University A course units are more willing to mix activities.

It is interesting to evaluate whether the recommended activity types correlate with the students' pre-tutorial activities. To investigate this question we report in Figure 1 kernel estimates of the distribution of preferred percentages of time students should work during tutorials. We report different distributions depending on how students answered to the question whether they watched the online clips before attending the tutorials (No, Yes one, Yes most or Yes all).

The distributions do clearly illustrate that the preferences of students that didn't watch any clips are such that they wish to see less time devoted to students working on problems during the tutorials. On the other extreme, students that watched all pre-tutorial clips wish to see most time dedicated to students working on problems during the tutorials. A mirror image of these results (not graphically shown here) arises when looking at the preferred percentage of time dedicated to the tutor solving problems on the board.

Interestingly the responses to the questions of preferred tutorial activities differ rather significantly between the University B and University A course units. This is illustrated in Figure 2 which is structured as Figure 1 just that the different distributions reflect the responses originating from different course units.

Most students from the University A course units (Introductory Statistics – A_Stats and Econometrics – A_Ecmtr) prefer a mixture of activities as very little probability mass arises at the extremes (0% or

100%). Students on University B's Quantitative Methods course unit (B_QM) however, often prefer one of the extremes.

5.2.3 Overall Student Evaluation

Lastly we ask students whether they prefer the traditional or the flipped tutorial format. We asked the same question in basically two ways:

- Question 6: (In this question, state your level of agreement with the statement) The tutorials this term with videos provided beforehand helped me understand the material better than the tutorials where we prepared work before the class and went through the material on the whiteboard.
- Question 7: (In this question, state your level of agreement with the statement) The tutorials last term where we prepared work before the class and went through material on the whiteboard helped me understand the material better than the tutorials this term where a video was provided beforehand.

Clearly we would expect students to not provide the same answer to both questions. As it turns out, students from University B by and large did indeed provide different answers. Students from the two University A course units, however, do provide a substantial amount of contradictory answers as can be seen from the tables 7, 8 and 9.

Looking at the results obtained from the students from University B, 57% of students unambiguously show a preference towards flipped tutorials. (Either agree completely, or agree somewhat that they prefer flipped (question 6), and disagree somewhat, or disagree completely that they prefer traditional tutorials (question 7)). For University A students, the results are somewhat more ambiguous, with 20% reporting an unambiguous preference towards flipped tutorials in statistics, and 17% for econometrics. This is somewhat counterintuitive, as, ignoring preferences towards the unflipped classes, 75% and 64% of students reported agreeing completely, agreeing somewhat that they preferred the flipped tutorials. This compares to the unconditional preference towards the flipped tutorials for University B students of 93%. On the whole, these results suggest a slight preference towards flipped tutorials in University A, and an unambiguous preference towards flipped tutorials in University B[10]. It is impossible to say why University A students responded in a rather inconsistent manner. Singer and Ye (2013) investigate whether the act of providing incentives (in this case additional exam revision resources) has repercussions on the quality of responses provided. Their review concludes that there is limited empirical evidence that investigates this question with some conflicting evidence. The possibility that the provision of these incentives elicited low quality responses cannot be excluded.

It is a rather interesting feature of the student feedback received that, when asked what activity they would prefer, they indicate that they do prefer to see the tutor solving problems on the board, but when asked to evaluate whether a flipped format improves their learning they do indeed indicate that the flipped format is beneficial. This somewhat curious finding confirms student feedback one of the authors received in previous years.

[10] In previous two years a very similar question was asked of University A students in Introductory Statistics and Econometrics and in excess of 70% of students indicated that they learned the material better through the flipped rather than the traditional tutorial. On these occasions we did not ask a similar "flipped" question.

Further to this, it is of interest to ask, under what circumstances students report a preference towards a flipped classroom. In order to attempt to assess why students may report preferences towards a flipped classroom, we consider a linear probability model. The dependent variable indicates whether a respondent agreed completely, or agreed somewhat that they preferred the flipped tutorial. Controls used are based on the responses to question 1, question 3 and question 4. Since some students responded in a somewhat ambiguous manner, in specification (ii) we omit students who reported that they both agreed somewhat, or agreed completely to both questions 6, that they preferred flipped classed, and question 7, that they preferred unflipped classes.

The results of the linear probability model are reported in Table 10. Unsurprisingly (and somewhat reassuringly), students who report to having watched all of the class videos are significantly more likely to unambiguously prefer the flipped tutorials to the unflipped tutorials. However, in our preferred specification (specification (ii)), whilst the point estimates are increasing in the engagement with videos, it is only the most engaged students who report a significant preference towards the flipped tutorials.

Similarly, students who engaged with the written exercises in advance of watching the videos (or prior to attending the tutorials) report preferring the flipped tutorials. As a prior, we might expect students who did not like the flipped tutorials to be likely to self-select out of tutorials, and not attend. However, self-reported attendance is not a significant predictor of a preference in either of our specifications.

Finally, comparing the two institutions, it is clear that students from University B are significantly more likely to prefer the flipped environment, in spite of the similarity of the two institutions. This suggests that there are areas of heterogeneity in terms of preferences towards the flipped classroom, which may be related to teaching staff, small group size, student intake, or other heterogeneity, which cannot be controlled for here.

5.3 Watching patterns

Here we analyse when students are actually watching the online clips. The flipped tutorials are structured to encourage students to watch the online clips in preparation for the actual tutorial meetings. One advantage of this structure is of course that the online clips can be made available for the entire academic term and therefore can also be used as a part of the student's revision process. Indeed, when asked whether students intend to use these clips in the run-up to the final examinations, they overwhelmingly (87%) indicate that they are very likely or certain to use the online clips in their revision. Of course, when making material available in this manner, academics tend to warn that students are likely to delay their studying to a time closer to the examination period. Elliott and Neal (2016) however find little evidence for such a substitution effect, neither in their analysis nor in the reviewed literature.

In the following Figures 3 and 4 we show daily viewing numbers for the tutorial clips produced for the tutorials in Econometrics and Introductory Statistics[11].

[11] Similar viewing patterns can be seen for University B, but due to a different video software package, the viewing patterns are not shown here.

Figure 3 clearly illustrates a number of features of how students use the online clips. There are clear initial viewing peaks leading up to the time of the actual tutorial class. Followed by a viewing spike in the immediate run-up to the mid-term test (14 March 2014). Finally we find viewing peaks associated with the exam (20 May 2016) revision period. These peaks are more intense for tutorial classes that are scheduled later in the semester, in particular after the mid-term test.

The viewing pattern for the Introductory Statistics online clips (Figure 4) are very similar to those for the Econometrics course unit. An initial viewing spike occurs in the respective tutorial week and then again pre-exam. For both course units we find that the initial viewing spike in the tutorial week becomes less intense as we progress into the semester. Conversely, the viewing of the online clips for later tutorials becomes relatively more intense in the exam revision period.

Students often mention that the later weeks in the semester are more intense than the earlier ones, often dominated by coursework deadlines. In such weeks it is quite likely that students decide to trade-off tutorial preparation time with an increased effort on coursework. Such a behaviour would contribute to the pattern of viewing behaviour we can see in Figures 3 and 4.

5.4 Evidence from interviews with students and tutors

We undertook a number of structured interviews with students (6 from University B and 4 from University A) and teaching assistants (2 from University A) to gain a deeper understanding of how students view the new tutorial set-up and in particular how they see the role of the tutor and the students themselves (see Appendix 1 for the questions that guided the interview process).

Students confirm that the role of the tutorials in the context of their entire learning process is that of reinforcing and deepening their understanding of the material taught in the course and to gain experience in applying this knowledge. In particular they hope that the tutor can contribute to this process by helping them with their understanding of the materials through personal interaction with the tutor.

The interviewed students generally supported the flipped tutorial reporting that they either attempted the published questions before watching the online clips or took notes during the clip to facilitate the subsequent solution of the problems. They also reported that they had used the clips as part of their exam revision process. Some students commented that they thought that clips could have benefitted from being shorter (clips tended to be between 40 and 60 minutes long) or closer in difficulty to those tackled in the actual tutorial and/or exam paper which were perceived as being more difficult.

There were varied reactions of students to being asked to tackle unseen questions in the tutorials; some feeling more pressured by this setup and others commenting that they appreciated the increased interaction between students. Some commented that they felt that this setup was responsible for decreasing tutorial attendance. In particular most interviewed students seemed to agree that having to tackle questions during tutorials had increased their confidence in tackling new questions.

The teaching assistants (TAs) interviewed report that tutorial attendance appears unaffected by the change in tutorial format. One of the interviewed TAs reports that students became less well prepared later in the semester, an observation that chimes with the pattern of viewing statistics we reported

earlier. But both TAs shared the view that students that came prepared to the flipped tutorials gained a deeper understanding of the material.

As the new format incorporates team building skills and presentation skills the TAs suggested that moving away from the traditional format is beneficial as it reduces the time tutors spend 'talking at' students and increased the space for working in groups. However, they did report a varying degree of students' keenness to work and interact in groups but did note that they had to field significantly more questions by students in the flipped format. Students not asking questions or interacting is often seen as a weakness of the traditional tutorial approach and hence this must be seen as a positive outcome of implementing a flipped tutorial approach.

The TAs did mention that they required a very different skill set when leading flipped tutorial classes. The lack of predictability of what problems and questions would arise meant that they felt that they needed a deeper understanding of the material themselves. Besides this they needed to have significant listening and observation skills in order to identify which groups are in need of TA intervention.

6. Discussion and Conclusion

In traditional small group classes, in the absence of an outstanding class leader, it is sometimes possible for students to find themselves engaged in passive learning. In order to improve the small group environment, University B and University A have introduced flipped teaching in a small group environment for a selected set of course units. In this paper, we have examined how students perceived the change to flipped tutorials, investigated how they use the online video clips and whether they do the expected pre-tutorial work.

Lage et al (2000) provide a similar evaluation of flipped teaching, and find an overall preference towards the flipped environment. Our results add further weight to students preferring the flipped environment, but there is a certain level of heterogeneity, between students, and between institutions. Unsurprisingly, students who interact with the preparation material report a strong preference towards the flipped environment. The underpinnings of the flipped environment is that students pick up the foundation cognitive skills (see, for example, Anderson and Krathwohl (2001)) in the preparatory work, outside of class, and then are able to develop the higher level cognitive skills through supported learning in the class. However, those students who do not engage with the videos are unlikely to be able to develop these higher level skills, as they are missing the foundations. This raises a possible risk of a flipped environment of disengaged students falling behind.

Whilst there are clear theoretical pedagogical benefits to the flipped environment, it was not possible to randomly assign students, within a cohort, to a flipped, and non-flipped teaching environment, so we were not able to quantitatively or causally assess the impact of the flipped teaching environment on academic results. However, we did establish that significant proportions of students display good studying behaviour as they watch pre-tutorial videos and work on questions and that, on average, students preferred this method of teaching over traditional classes. Several pedagogical advantages exist, including the opportunity to build higher level cognitive skills, and offering students the opportunity to work within small groups, jointly developing answer to unseen questions. In addition,

students clearly value the extra resource made available in the form of videos when it comes to revision for examinations.

In the absence of a causal identification strategy we cannot draw any conclusion as to the quantitative effect a flipped tutorial structure. Establishing such effects has been notoriously difficult in the educational literature. We do conjecture that flipped tutorials contribute positively to students' levels of academic achievement, and indeed student satisfaction but are encouraging researchers and teachers to propose experimental setups that would allow clear causal judgements.

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Tables and figures

Table 1. Summary Statistics on courses covered and on viewing behaviour.

	Intro Stats (University A)	Econometrics (University A)	Quant. Methods (University B)
Respondents	181	208	160
% of enrolled	74%	49%	53%
Average group size	31	47	15
Watch online clips before tutorial?			
No	14%	10%	8%
Watched one	13%	14%	8%
Watched most	52%	47%	39%
Watched all	21%	27%	49%

Table 2. Response frequencies to the questions on viewing behaviour and attendance frequency for the Introductory Statistics (University A) course unit.

Intro Stats		Attended				
		No	Yes one	Yes most	Yes all	Total
Online Clip	No	2.78%	3.33%	7.22%	1.11%	14.44%
	Yes one	1.11%	2.22%	7.78%	1.67%	12.78%
	Yes most	2.22%	4.44%	35.56%	10.00%	52..22%
	Yes all	0.56%	1.67%	7.22%	11.11%	20.56%
	Total	6.67%	11.67%	57.78%	23.89%	100%

Table 3. Response frequencies to the questions on viewing behaviour and attendance frequency for the Quantitative Methods (University B) course unit.

Quant Meth		Attended				
		No	Yes one	Yes most	Yes all	Total
Online Clip	No	0.63%	0.62%	3.13%	3.13%	7.50%
	Yes one	0%	1.25%	5.63%	1.25%	8.13%
	Yes most	0%	1.88%	12.50%	20.63%	35.00%
	Yes all	0%	0%	15.63%	33.75%	49.38%
	Total	0.63%	3.75%	36.88%	58.75%	100%

Table 4. Response frequencies to the questions on viewing behaviour and attendance frequency for the Econometrics (University A) course unit.

Econometrics		Attended				
		No	Yes one	Yes most	Yes all	Total
Online Clip	No	1.47%	1.47%	4.90%	2.45%	10.29%
	Yes one	0.49%	1.47%	5.88%	6.86%	14.71%
	Yes most	1.47%	1.96%	18.14%	25.49%	47.06%
	Yes all	0%	0%	6.86%	21.08%	27.94%
	Total	3.43%	4.90%	35.78%	55.88%	100.00%

Table 5. Response frequencies to the questions on viewing behaviour and pre-tutorial work for all three course units.

All		*Work on problems*				
		No attempt	0-30 mins	30-60 mins	> 60 mins	Total
Online Clip	No	6.08%	2.95%	1.47%	0.37%	10.87%
	Yes one	2.58%	4.79%	4.05%	0.74%	12.15%
	Yes most	4.24%	15.29%	20.07%	5.71%	45.30%
	Yes all	4.24%	9.76%	10.50%	7.18%	31.68%
	Total	17.13%	32.78%	36.10%	14.00%	100.0%

Table 6: Percentages of time students would allocate to the respective activities. "% of zeros% indicates what percentage of students would prefer not to spend any time on the particular activity.

	Activity		
	Students working on unseen questions and tutors supervising	Students presenting solutions on the whiteboard to the whole class	Tutor working through questions on the board
Mean	34.10	15.42	48.68
Sd	24.06	16.60	26.21
% of zeros	13	35	7
Lower Q	20	0	30
Median	30	10	50
Upper Q	50	25	60
Max	100	100	100

Table 7: Students' reported preferences between flipped and traditional tutorials. University A, Intro to Statistics.

		Prefer traditional					
		Agree completely	Agree somewhat	Neither agree nor disagree	Disagree somewhat	Disagree completely	Total
Prefer flipped	Agree completely	8%	12%	9%	8%	4%	41%
	Agree somewhat	7%	14%	6%	7%	1%	34%
	Neither agree nor disagree	3%	3%	6%	2%	0%	14%
	Disagree somewhat	3%	3%	1%	1%	0%	7%
	Disagree completely	2%	0%	0%	0%	0%	2%
	Total	24%	33%	21%	17%	5%	100%

Table 8: Students' reported preferences between flipped and traditional tutorials. University A, Econometrics

		Prefer traditional					
		Agree completely	Agree somewhat	Neither agree nor disagree	Disagree somewhat	Disagree completely	Total
Prefer flipped	Agree completely	7%	4%	5%	6%	4%	26%
	Agree somewhat	4%	14%	12%	7%	0%	38%
	Neither agree nor disagree	1%	4%	10%	1%	0%	16%
	Disagree somewhat	3%	7%	1%	0%	0%	12%
	Disagree completely	4%	1%	0%	0%	0%	5%
	Total	19%	32%	28%	14%	4%	100%

Table 9: Students' reported preferences between flipped and traditional tutorials. University B, Quantitative Methods.

		Prefer traditional					
		Agree completely	Agree somewhat	Neither agree nor disagree	Disagree somewhat	Disagree completely	Total
Prefer flipped	Agree completely	6%	3%	12%	26%	18%	64%
	Agree somewhat	3%	6%	8%	12%	1%	29%
	Neither agree nor disagree	0%	0%	3%	0%	1%	3%
	Disagree somewhat	0%	1%	0%	2%	1%	3%
	Disagree completely	0%	0%	0%	0%	1%	1%
	Total	9%	9%	22%	40%	21%	100%

Table 10 Linear probability model of which students report preferring the flipped tutorials.

		(i)	(ii)
Did you watch the video prior to the tutorials. (Base = "No")	Yes, one	0.117	0.077
		(0.088)	(0.123)
	Yes, most	0.160**	0.130
		(0.076)	(0.102)
	Yes, all	0.321***	0.290***
		(0.075)	(0.101)
How long did you spend attempting the exercises prior to watching the video. (Base = "I did not attempt")	0 to 30 minutes	0.068	0.065
		(0.061)	(0.079)
	30 minutes to 1 hour	0.173***	0.169**
		(0.059)	(0.078)
	More than 1 hour	0.206***	0.187**
		(0.065)	(0.086)
Did you attend the tutorials in semester 2? (Base = "No")	Yes, one	0.039	0.041
		(0.127)	(0.165)
	Yes, most	0.123	0.148
		(0.104)	(0.136)
	Yes, all	0.079	0.153
		(0.106)	(0.138)
Course (Base = University A, Intro Stats)	University A, Econometrics	-0.130***	-0.084
		(0.046)	(0.067)
	University B, Quantitative methods	0.106***	0.169***
		(0.039)	(0.056)
	R^2	0.19	0.22
	N	536	338

Notes: * $p<0.1$; ** $p<0.05$; *** $p<0.01$, heteroscedasticity robust standard errors in parentheses. Dependent variable is a dummy variable that takes the value 0 if a student reports that they disagree completely, disagree somewhat, or neither agree nor disagree that they prefer the flipped classroom. In specification (ii), we drop students who report that they both preferred the flipped and the unflipped environment.

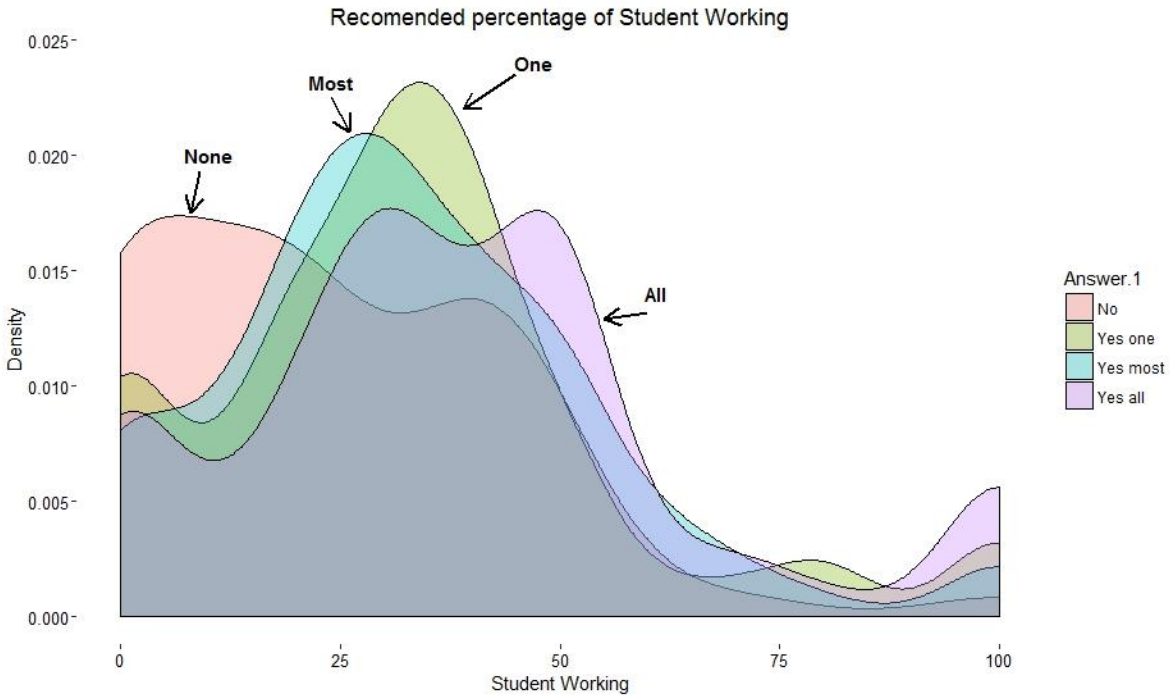

Figure 1: Kernel estimates of preferred percentage of time dedicated to students working during tutorials. The different kernel estimates are reflective of students' different pre-tutorial viewing behaviour (Answer.1, Have you watched the pre-tutorial clip? Answers: No, Yes one, Yes most or Yes all).

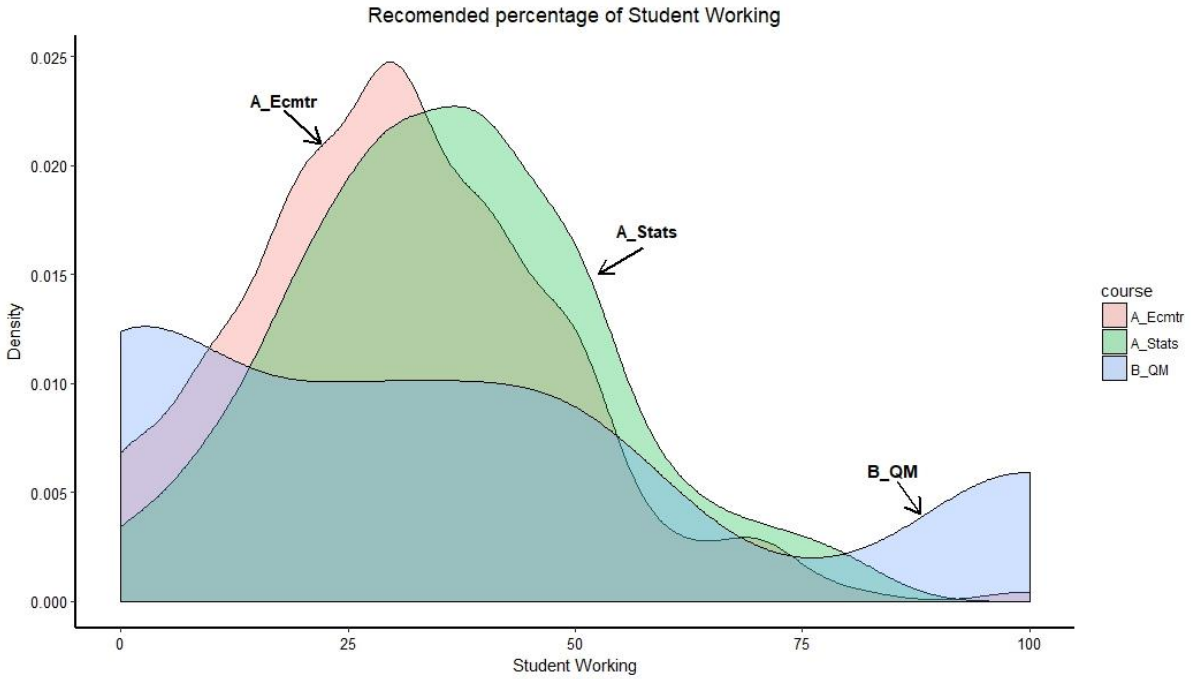

Figure 2: Kernel estimates of preferred percentage of time dedicated to students working during tutorials. The different kernel estimates are reflective of the different course units.

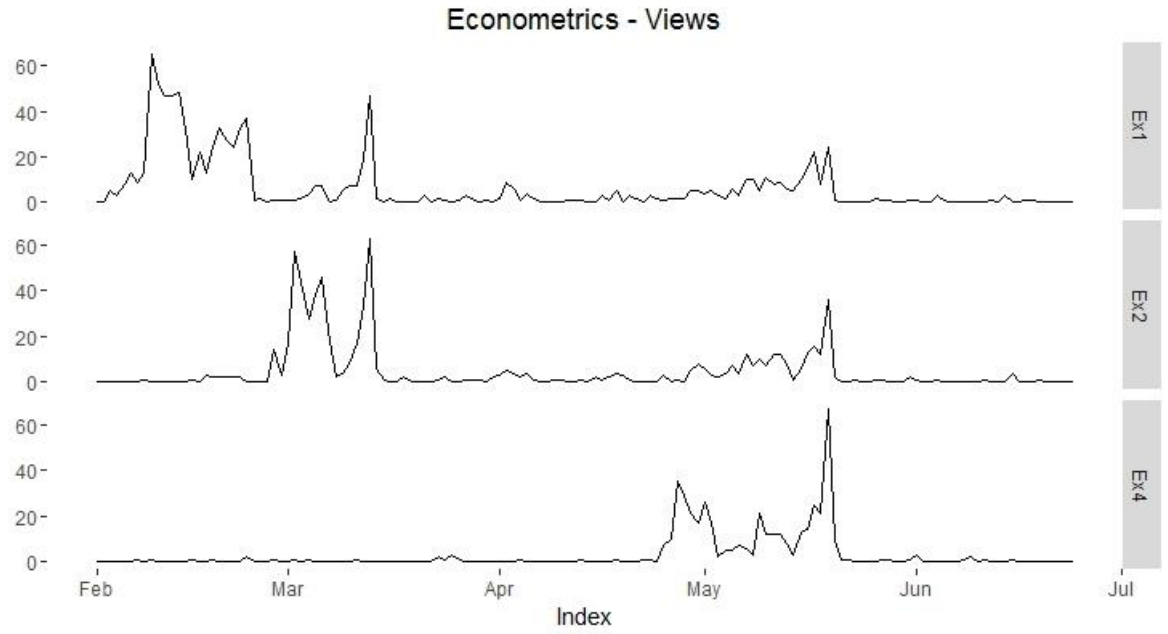

Figure 3: Daily viewing figures for the tutorial problem clips for the University A course in Econometrics. This course unit had four tutorials in Semester 2 and here we show the viewing numbers for classes 1, 2 and 4 (Ex1, Ex2 and Ex4). The viewing figures for the third could not be retrieved. A mid-term exam was held in the middle of March and the final exam was held around the 20th of May.

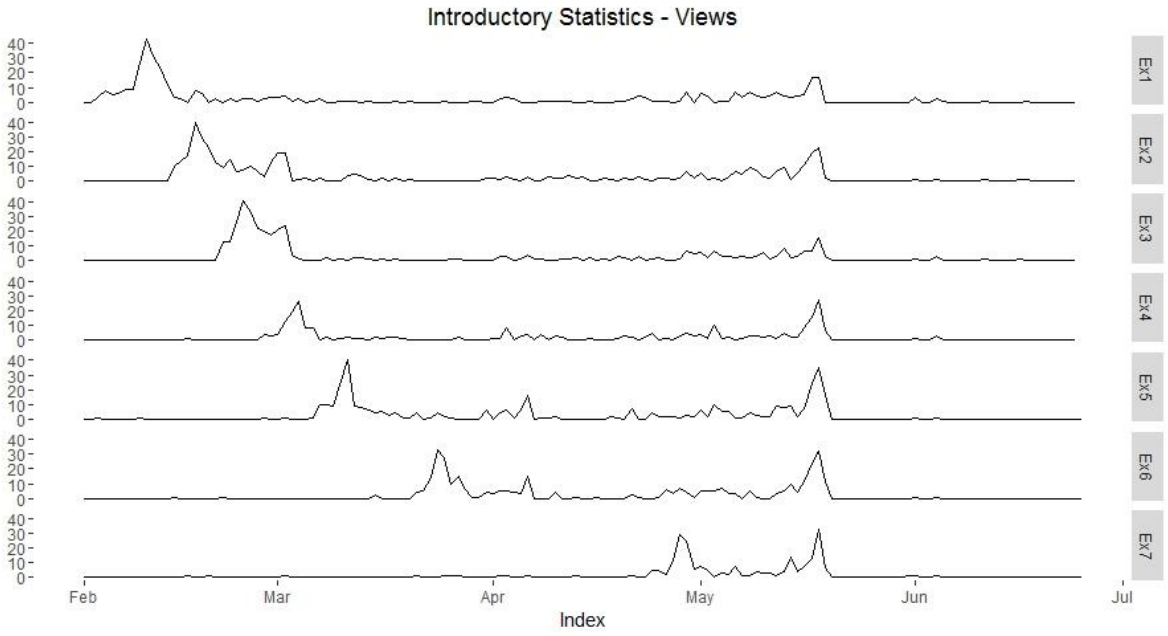

Figure 4: Daily viewing figures for the tutorial problem clips (Ex1 to Ex7) for the University A course in Introductory Statistics. This course unit had seven tutorials in Semester 2. The final exam was held around the 20th of May.

Appendix 1 – Interview Structure

A research assistant who was not otherwise involved in the delivery of any of the course units was tasked with interviewing students and teaching assistants and subsequently transcribing and summarising their responses. The students who agreed to partake in these interviews were self-selected volunteers and consequently their responses cannot be seen as representative for their peers. The interviews were held in the exams period.

The following is a list of the questions that provided the structure of the interviews:

STUDENTS

- What do you believe is the primary purpose of small group tutorials?
- What do you believe is the role of the tutor in a small group tutorial?
- What do you hope to gain from tutorials?
- How would you like tutorials to be structured so that you can get the most from them?
- Have you watched any of the online videos? If so, how many have you watched?
- When did you watch them? Did you watch them prior to the tutorial? Will you watch them again?
- How did you watch them? Had you prepared the work prior to watching the video, did you use them as preparation for the tutorial or did you merely watch them to get solutions?
- Did watching the video affect either your motivation or your actual attendance at tutorials?
- Did the videos affect your ability to attempt unseen questions? If so, did they make the tutorials easier?
- Compared with your other subjects, do you generally attend tutorials in this subject the same, more, or less?
- Do you feel that the videos have affected your learning within tutorials?
- Do the videos make tutorial attendance 'easier' because you have a better understanding?
- Compared with other subjects, how much time do you spend preparing for tutorials in this subject?
- If so, what is it about the subjects that makes a difference?
- Do you feel more, or less, under pressure in tutorials where you are asked to attempt an unseen exercise than in tutorials where you have been asked to prepare work and bring it along to discuss?
- How does the tutorial experience compare between different structures of tutorial?
- Do you feel that your tutor made a positive contribution to your understanding of the material?
- How does that compare to tutorials with a more traditional structure?
- During your revision for your exams, have you attempted any past papers for this subject, or any other subject?
- Have you used the videos within your revision process? How have you used the videos, and do you feel that they have assisted you in learning how to begin problems?
- Do you feel that the structure of videos and unseen exercises will affect your performance in the examination?
- Do you have any further comments about the structure of tutorials using online videos?

TUTORS

- Compared to Semester 1 tutorials (in the traditional style) how would you rate the tutorial attendance?
- How well were students prepared for the tutorials? And how did that compare to the tutorials in Semester 1?
- Were you able to comment on individual student's workings during the tutorial? And how did that compare to the tutorials in Semester 1?
- Were you able to gain an insight into students' problems with the material? And how did that compare to the tutorials in Semester 1?
- In your opinion did students get a deeper understanding of the material during the tutorials? And how did that compare to the tutorials in Semester 1?
- Do you think that you were able to build "relationships/rapport" with students during the tutorials? And how did that compare to the tutorials in Semester 1?
- Did students mainly work individually or in small groups?
- If they worked in groups, please comment how willing they were to do so and whether you think that student's benefitted from this.
- How do you think does this tutorial format cater for different student skills? And how did that compare to the tutorials in Semester 1?
- What are the different skills required by the teaching assistants in that tutorial format?
- Were you well enough prepared for this flipped tutorial format?